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CCSR Cooperative Agreement - Final Progress Report 1995

The Center for Climate Systems Research: Interdisciplinary Climate Applications Studies

Statement of Purpose

The Center for Climate Systems Research (CCSR) is an official vehicle for the cooperative relationship between Columbia University and the NASA Goddard Institute for Space Studies. CCSR was established in 1994 for the purpose of enhancing the program of interdisciplinary Earth systems research between Columbia and NASA/GISS. The overriding objective of all projects conducted under the auspices of CCSR is to provide an enhanced understanding of the Earth's climate sensitivity and variability, as well as the forcing and feedback mechanisms that control them. The center is especially concerned with aspects of the climate system that have the potential to impact human populations and environmental stability.

1995 Results of Individual Investigator's Research

Dr. Mark A. Chandler,
Principal Investigator, Associate Research Scientist

Warm climates, both in the past and in the future, were the focus for 1995. Two time periods in the geologic past were of particular interest: the middle Pliocene Epoch approximately 3 million years ago and the Paleocene/Eocene boundary period, which is pegged at about 58 million years ago. Both periods are of interest not only because evidence shows that they were much warmer than the present climate, but because the cause of warming is suspected to have been altered ocean circulation patterns in both cases.

Oceans play a primary role in global climate change on many time scales. Geologic records from a variety of warm periods support the contention that altered ocean heat transports contributed to the increased global temperatures of those eras. Ice core records from Greenland, ocean cores from the North Atlantic, and tree ring records also show evidence of a variable ocean circulation system that influences regional as well as global climates.

Another topic which we devoted much time to this year also relates ocean circulation change and climate change. A General Circulation Model (GCM) study, using the GISS GCM Model II, focused on the potential for future changes in ocean heat transport to amplify or mitigate the global warming trend caused by anthropogenic trace gas increase. The oceans and atmosphere are linked through a variety of ocean, atmosphere and sea ice feedbacks. Some of these feedbacks are, potentially, of first-order importance in the climate system. Furthermore, they are also unaccounted for, or inadequately included, in previous global warming simulations. Thus, current estimates of the greenhouse effect may not represent the true range of potential climates for the next century. Impact assessments must account for the potential effects of the oceans, in addition to increasing greenhouse gases, on the changing climate in order to appropriately plan for the future and to accurately assess regional risks. Our experiments are providing a first step in estimating more accurately the full range of possible climates that may result from the anthropogenic alteration of the environment.

In conducting simulations of the Pliocene climate, calculations of the approximate Pliocene ocean heat transport levels for the world's oceans were accumulated. These ocean heat transport values, which are higher than present day estimates of ocean heat flux, were then used to force a GCM simulation (OHT+) that also included the estimated rise in greenhouse gases. The simulation was then started from conditions representing the year 1958 and continued to the year 2100. The results were then compared to two additional simulations: 1) a simulation with forcing provided only by greenhouse gas increase and *modern (unchanged)* ocean heat transports and 2) a simulation with increasing greenhouse gases plus *decreased* ocean heat transports (OHT-).

The initial results of these experiments reveal that dramatic adjustments to present estimates of global warming would be required if it turns out that ocean circulation changes occur in the future. Global warming in the experiments (OHT+, OHT-) ranges from 4.5 to 6.5 degrees over the next century and temperature change in certain regions, such as the northeastern United States and western Europe, ranges from cooler than present to +15 °C, strictly a result of altered North Atlantic heat transports and the resulting feedback effects. The temperature time series results and global average changes were presented at two national meetings in 1995 and animations of the experiments have been created. Our task for much of 1996 will be to analyze the regional temperature effects of the ocean heat change experiments and to begin examining the hydrological effects of such changes. A paper describing our ocean heat transport experiments is completed and will be submitted after internal review. Another manuscript describing our most recent Pliocene work is in preparation together with colleagues at the U. S. Geological Survey, and a paper on thermohaline circulation changes that effected the Paleocene/Eocene global warming is in press and due out in Spring 1996.

Dr. Katherine Pierce Shah
Associate Research Scientist

Deep tropospheres, mid-tropospheres, tropopauses and lower stratospheres of the NASA/GISS atmospheric GCM and the Global Climate\Middle Atmosphere Model (GCMAM) and their experiments were evaluated by Kathryn Shah with global microwave satellite data in 1995. Her radiative transfer model uses a model's 3D atmosphere and its surface to calculate maps of brightness temperatures -- microwave snapshots of a GCM or GCMAM atmosphere. The GCM and GCMAM microwave maps were thus directly compared to Microwave Sounding Unit (MSU) maps. This assessed monthly mean states and variability for model developmental work. With climate experiments incorporating different anthropogenic forcings, these microwave maps also determined when and where microwave signatures of forcings emerge from natural noise in satellite microwave data.

Assessment and optimization of advanced versions of the NASA/GISS GCM and GCMAM was aided by the microwave postprocessor. Higher vertical resolution and new positioning of the GCM's rigid top was examined. The microwave model was enhanced to handle diagnostics from a 31-layer GCM, versus the earlier 9 and 18-layer GCM versions, and from a GCM top moved from the lower stratosphere into the mesosphere. As the microwave brightnesses are sensitive to correct positioning and strengths of GCM heat transport mechanisms, numerous GCM versions were examined with new horizontal and vertical heat, momentum, and moisture diffusions added. The MSU channels measure several, disparate vertical sections of an atmosphere -- all of which aid optimization of a GCM via the extended microwave model.

A series of GCMAM climate experiments simulating the effect of current and 2015 supersonic and subsonic aircraft fleets on atmospheric ozone and water vapor were explored. The microwave postprocessor's maps determine the strength and significance of aircraft emission signatures above ambient microwave variability. This material was presented by Dr Shah at two conferences in 1995. "Supersonic Aircraft Emission Signals in Satellite and GCMAM Microwave Maps" appeared at the 5th Annual Meeting on Atmospheric Effects of Aviation Project at Virginia Beach, VA, in April 1995. A polished version of this supersonic aircraft talk plus preliminary subsonic aircraft results were presented at the 21st General Assembly of the International Union of Geodesy and Geophysics in Boulder, CO, in July 1995.

Several publications arose in 1995 from the above model development and climate analysis work of Dr Shah. Shah and Rind (1995)'s "Use of Microwave Brightnesses Temperatures with a General Circulation Model" appeared in the Journal of Geophysical Research in July. Shah et al. (1995) "Could High-Speed Civil Transport Aircraft Impact Stratospheric and Tropospheric Temperatures Measured by MSU?" was submitted to the Journal of Geophysical Research in August 1995. Dr Shah also participated in the following papers as a co-author: Druyan et al. (1995) "Impacts of Model Improvements on General Circulation Model Sensitivity to Sea-Surface Temperature Forcing" in the International Journal of Climatology: Hansen et al. (1995) "A Pinatubo Climate Modeling Investigation" in the NATO Advanced Science Institutes Series; Hansen et al. (1995) \ "Satellite and Surface Temperature Data at Odds?" in

Climate Change; and, Gurwell et al. (1995) "Observations of the CO Bulge on Venus and Implications for Mesospheric Winds" in Icarus. Lastly, Dr Shah contributed by reviewing several papers for scientific journals.

Dr. Greg Hartke
Associate Research Scientist

A preliminary version of a new boundary layer model has been developed for the GISS GCM. The previous boundary layer model amounts to a complex interpolation scheme for the surface winds and fluxes of momentum, heat, and moisture. The new model solves the prognostic equations for the winds, temperature, and moisture mixing ratio on a sub-grid constructed between the surface and the middle of the first model layer. A second-order closure model is used to compute the transport coefficients in the new boundary layer and similarity theory is used to compute the transports in the surface layer. Much testing and further improvement remains before this new model will be ready for GCM production, but preliminary test runs are most encouraging. The new model represents a major step in upgrading this segment of the GISS GCM to modern standards.

Testing of the eddy-damped quasi-Lagrangian Markovian (EDQLM) turbulence model has been completed for isotropic turbulence at both low and high Reynolds numbers. The important feature of the new model is that its computational strucuture is much simpler than that of extant turbulence theories. The comparison entailed computing statistical properties of an appropriate flow using the direct interaction approximation (DIA) as the baseline for the low Reynolds number flow and two versions of the Lagrangian history DIA for the high Reynolds number flow. The statistics computed using the EDQLM model compared very favorably to those obtained using the established theories. A serious problem was encountered when it was discovered that the published version of the Lagrangian history DIA had numerous mistakes but this was overcome through discussions with the author of the paper describing the theory. A paper detailing the new turbulence model and the comparison with the established theories is in preparation and will be submitted to Physics of Fluids.

The coding for the linearized chemistry of N2O and CO2 has been included in the tracer version of the GCM. This work includes the computation of the losses of these two species in the stratosphere. The chemistry and losses for ozone are next to be included in this version of the GCM.